Birla Institute of Technology & Science, Pilani
Work Integrated Learning Programmes Division
First Semester 2026-2027

Digital Learning Handout

Part A: Content Design

Course Title	Unsupervised Deep learning
Course No(s)	AIML ZG533
Credit Units	4
Credit Model	3-1-0
Course Author	Sugata Ghosal
Instructor	Hema Aparna Madicharla (lead), MINATI RATH
Version No:	2.0 (Earlier Advanced Deep Learning renamed as Unsupervised Deep Learning)
Date:	27/02/2025

Course Description:

Introduction to Representation Learning, PCA and variants, likelihood-based models, flow models, autoregressive models, latent variables, Deep autoencoders, Boltzmann Machines, Generative Adversarial learning, Variants of GAN and applications, DeepDream, neural style transfer, self-supervised learning, semi-supervised learning, language model learning, applications in time series modelling, representation learning for reinforcement learning, deep clustering

Course Objectives

No	Course Objective
CO1	Learn about foundational principles of unsupervised deep learning
CO2	Learn about semi-supervised and self-supervised deep learning
CO3	Learn about representation learning
CO4	Learn about generative modelling and applications

Text Book(s):

T1	Understanding Deep Learning, The MIT Press., 2023, Simon J.D. Prince
T2	Deep Learning (Adaptive Computation and Machine Learning series) Hardcover – 18 November 2016, Aaron Courville, Ian Goodfellow, Yoshua Bengio

Reference Book(s) & other resources:

R1	Hands-On Machine Learning with Scikit-Learn, Keras, and TensorFlow:

	Concepts, Tools, and Techniques to Build Intelligent Systems, Aurélien Géron
R2	Deep Learning with Python, François Chollet
	Research Papers, Blogs

Learning Outcomes: Students will be able to

LO1	Gain a strong understanding of the foundations of deep unsupervised learning
LO2	Solve problems using appropriate unsupervised learning techniques
LO3	Gain a strong understanding of the foundations of generative modeling

Modular Content Structure

1. Introduction
- Unsupervised, semi-supervised, self-supervised learning
- Representation learning
- Generative Modeling

2. PCA variants
- Randomized PCA
- Incremental PCA
- Kernel PCA
- Probabilistic PCA
- Sparse PCA
- Canonical Correlation Analysis (CCA)
- Locally Linear Embedding (LLE)
- Independent Component Analysis
- Factor Analysis
- Manifold learning

3. Autoencoders
- Type of activation and loss functions
- Undercomplete Vs. Overcomplete autoencoders
- Relationship with PCA
- Regularization
  - Denoising autoencoder
  - Sparse autoencoder
  - Contractive Autoencoders
- Effect of Depth
- Application of Autoencoders

4. Autoregressive Models

- Motivation
- Simple generative models: histograms
- Parameterized distributions and maximum likelihood
- Recurrent Neural Nets
  - Masking-based Models
    - Masked AEs for Distribution Estimation (MADE)
    - Masked Convolutions
      - WaveNet
      - PixelCNN and Variants
  - Applications in super-resolution, colorization
  - Speed Up Strategies

5. **Normalizing Flow Models**

- Difference with AR Models
- Foundations of 1-D Flow
- 2-D Flow
- N-dimensional flows
  - AR and inverse AR flows
  - NICE/ RealNVP
  - Glow, Flow++
- Dequantization
- Applications in super-resolution, text/audio synthesis, point cloud generation

6. **Variational Inteferencing**

- Latent Variable Models
- Training Latent Variable Models
  - 6.2.1 Exact Likelihood
  - 6.2.2 Sampling; Prior, Importance
  - 6.2.3 Importance Weighted AE
- Variational/Evidence Lower Bound
- Optimizing VLB/ELBO
- VAE Variants: VQ-VAE, AR_VAE, Beta VAE
- Variational Dequantization

7. Generative Adversarial Network

- Principles
- Minimax optimization
- DCGAN
- Variants
  - Wesserstein GAN
  - Conditional GAN
  - Cycle GAN
  - Style GAN

- Applications of GAN

8. Denoising Diffusion Models

- Diffusion Probabilistic Models
- Denoising Diffusion Probabilistic Models
- Denoising Diffusion Implicit Model
- Applications

9. Energy and Score-Based Models

- Parametrizing probability distributions
- Energy-based generative modeling
- Ising Model, Product of Experts, Restricted Boltzmann machine,
- Deep Boltzman Machines
- Training and sampling from EBMs
- Score-based Models

10. Language Modeling

- Motivation and Introduction
- Introduction to Language Models
- A digression into Transformer, word2Vec, BERT, ..., GPT

11. Time Series Modeling and Generation

- Advanced VAE and GAN techniques for modelling of time-series data
- Generation of time-series data (ARIMA, S-ARIMA etc.)

Part B: Learning Plan

Contact Session	List of Topic Title	Sub-Topics	Reference
1	**Introduction**	Unsupervised, semi-supervised, self-supervised learning; Representation learning; Refresher of supervised deep learning	Lecture Slides
2	**PCA and Variants**	Randomized PCA, Incremental PCA, Kernel PCA, Probabilistic PCA, Sparse PCA, Canonical Component Analysis, Locally Linear Embedding (LLE), Independent Component Analysis, Factor Analysis, Manifold learning	Lecture Slides
3	**Autoencoders**	Type of activation and loss functions,	Lecture

		Undercomplete Vs. Overcomplete autoencoders, Relationship with PCA	Slides
4	**Autoencoders**	Regularization such as Denoising autoencoder, Sparse autoencoder, Contractive Autoencoders, Effect of Depth, Application of Autoencoders	Lecture Slides
5	**Autoregressive Models**	Motivation, Simple generative models: histograms, Parameterized distributions and maximum likelihood, Recurrent Neural Nets, Masking-based Models, Masked AEs for Distribution Estimation (MADE), Masked Convolutions, WaveNet , PixelCNN and Variants Applications in super-resolution, colorization	Lecture Slides
6	**Normalizing Flow Models**	Difference with AR Models, Foundations of 1-D Flow, 2-D Flow, N-dimensional flows, AR and inverse AR flows, NICE/ RealNVP , Glow, Flow++, Dequantization, Applications in super-resolution, text/audio synthesis, point cloud generation	Lecture Slides
7	**Variational Inferencing**	Latent Variable Models, Training Latent Variable Models, Exact Likelihood, Sampling; Prior, Importance Weighted AE, Variational/Evidence Lower Bound, Optimizing VLB/ELBO, VAE Variants: VQ-VAE, AR_VAE, Beta VAE, Variational Dequantization	Lecture Slides
8	**Review**	Review of Session 1 to 7	Lecture Slides
9	**Generative Adversarial Networks**	Principles, minimax optimization, DCGAN	Lecture Slides
10	**Generative Adversarial**	Other variants of Generative Adversarial Networks	Lecture Slides

	Networks	Cycle GAN, Style GAN, Applications of GAN	
11	**Diffusion Model**	Diffusion Probabilistic Models, Denoising Diffusion Probabilistic Models, Denoising Diffusion Implicit Model, Applications	Lecture Slides
12	**Energy and Score Based Models**	Parametrizing probability distributions, Energy-based generative modelling, Ising Model, Product of Experts, Restricted Boltzmann machine, Deep Boltzman Machines, Training and sampling from EBMs, Score-based Models	Lecture Slides
13	**Language Modeling**	Motivation and Intro, Introduction to Language Models, History of Neural Language Models	Lecture Slides
14	**Language Modeling**	A digression into Transformer, word2Vec, BERT, …., GPT	Lecture Slides
15	**Time-Series Modeling**	Advanced VAE and GAN techniques for modelling and generation of time-series data (ARIMA, S-ARIMA etc.)	Lecture Slides
16	**Review**	Review of contact session 9 to 15	

Experiential Learning Components:

Describe objective, outcome of Experiential Learning Component and the lab infrastructure needed (virtual, remote, open source etc...) number of lab exercises needed, etc.

1. Lab work: 5
2. Project work: 0
3. Case Study: 4 Webinars
4. Simulation: 0
5. Work Integrated Learning Assignment- 2 Assignments
6. Design work/ Field work: 0

Objective of Experiential Learning Component:

Hands on sessions on implementation of representation learning and new data generation using state of art tools

Scope of Experiential Learning Component:
Programming language - Python
Tools and libraries: Jupyter, Scikit-Learn, Keras, Tensorflow etc
Lab Infrastructure:
Online/ Open source/Google Colab
List of Experiments:

Lab No	Lab Objective	Session Reference
1	Autoencoders	4
2	Deep Autoencoders	4
3	Convolutional Autoencoders	4
4	Variational Autoencoders	7
5	Generative Adversarial Networks	10

Evaluation Scheme:
Legend: EC = Evaluation Component; AN = After Noon Session; FN = Fore Noon Session

Evaluation Component	Name (Quiz, Lab, Project, Mid-term exam, End semester exam, etc.)	Type (Open book, Closed book, Online, etc.)	Weight	Duration	Day, Date, Session, Time
EC – 1*	Quiz	Online	10%	1 week	August 10-20, 2026
	Assignment/Lab Assignment / Lab Exams	Online	20 %	10 days	August 27-7 Sept 2026
EC - 2	Mid-Semester Test	Closed Book	30%	2 hours	20/09/2026 (FN)
EC - 3	Comprehensive Exam	Open Book	40%	2 ½ Hours	06/12/2026 (FN)

EC1* (20% - 30%): Quiz (optional): 5-10 %, Lab Assignment/Assignment: 20% - 30%
Syllabus for Mid-Semester Test (Closed Book): Topics in Contact session: 1 to 8

Syllabus for Comprehensive Exam (Open Book): All topics

Important Links and Information:

eLearn Portal: https://elearn.bits-pilani.ac.in

Students must visit the eLearn portal regularly and stay updated with the latest announcements and deadlines.

Contact Sessions: Students should attend the online lectures as per the schedule provided on the eLearn portal.

Evaluation Guidelines:

1. EC-1 consists of either two Assignments or three Quizzes. Students will attempt them through the course pages on the eLearn portal. Announcements will be made on the portal in a timely manner.
2. For Closed Book tests: No books or reference material of any kind will be permitted.
3. For Open Book exams: "open book" means text/ reference books (publisher copy only) and does not include any other learning material. No other learning material will be permitted during the open book examinations. For Detailed Guidelines refer to the attached document.
   EC3 Guidelines
4. If a student is unable to appear for the Regular Test/Exam due to genuine exigencies, the student should follow the procedure to apply for the Make-Up Test/Exam, which will be made available on the eLearn portal. The Make-Up Test/Exam will be conducted only at selected exam centres on the dates to be announced later.

It shall be the responsibility of the individual student to be regular in maintaining the self-study schedule as given in the course handout, attend the online lectures, and take all the prescribed evaluation components such as Assignments/Quizzes, Mid-Semester Tests and Comprehensive Exams according to the evaluation scheme provided in the handout.

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